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(54) A process and system for detecting misfiring in internal combustion engines

Verfahren und System zur Erfassung von Verbrennungsaussetzern bei Brennkraftmotoren

Procédé et système de détection des râtés d'allumage dans des moteurs à combustion interne

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(73) Proprietor: **MAGNETI MARELLI S.p.A.**
20145 Milano (IT)

(72) Inventors:
- **Palazzetti, Mario**
  I-10051 Avigliana (Torino) (IT)
- **Ponti, Cesare**
  I-10051 Avigliana (Torino) (IT)
- **Di Leo, Luigi**
  I-10078 Venaria Reale (Torino) (IT)

(74) Representative: **Bosotti, Luciano et al**
c/o JACOBACCI & PERANI S.p.A.
Corso Regio Parco, 27
10152 Torino (IT)

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- **PATENT ABSTRACTS OF JAPAN vol. 7, no. 254 (M-255) (1399) 11 November 1983 & JP-A-58 138 271 (MITSUBISHI JIDOSHA KOGYO KK) 17 August 1983**

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Description

Field of the invention

The present invention relates in general to the problem of detecting loss of combustion ("misfires" or "misfiring") in the operation of an internal combustion engine, for example in internal combustion engines mounted on motor vehicles such as motor cars.

The term loss of combustion (or misfire) indicates an anomalous situation in the normal operation of the engine.

The air-petrol mixture introduced into the cylinder does not generate the normal chemical reaction of a combustion engine, but is expelled completely or partially unburnt into the exhaust. As an immediate effect this generates an instantaneous loss of engine torque.

The unburnt mixture arrives at the exhaust where it burns causing an increase in the temperature of the silencer.

In the case of engines having catalytic converters in their silencers this increase in heating is the main cause of damage to the catalyser

Misfires can arise following:

- malfunctioning of an injector
- loss of spark from a spark plug
- mixture too lean or too rich.

Misfires can cause more or less damage according to the timing and number of misfires which occur.

For example, a misfire generated with the engine at full power is more serious than one at partial power, and a train of misfires (a series of consecutive combustion losses) is more damaging than a number of single and isolated misfires.

The increasing sensitivity to the problems of protection of the environment leads, as is known, to the definition of ever more stringent regulations in relation to the polluting emissions of internal combustion engines and to the phenomena attributed to such emissions. For example, the Californian CARB OBD-2 Regulation, which will come into force in 1996 throughout the entire territory of the United States requires, among other things, detection of misfiring.

The identification of this anomaly will have to be indicated to the user by the activation of an alarm (warning light on the dashboard, which illuminates and cannot be extinguished). This function is intended to protect the catalytic converter in the silencer.

The application of the OBD-2 Regulation could cause serious inconvenience to the user who, at each operation of the alarm, could be constrained to go to a garage. On the other hand, if the engine is equipped with an automatic injection calibration system capable of maintaining it always perfectly centred, this significantly reduces the probability that the OBD-2 alarm will activate.

Description of the prior art

The most widely known methods for the diagnosis of misfiring are:

- analysis of the signal representing the pressure in the combustion chamber (in the presence of misfiring a very much smaller pressure peak is recorded than in normal operation);
- analysis of the light emission generated by the combustion of the air-petrol mixture.

In earlier European Patent Application EP-A-0 408 518 there has been described the possibility of correlating the occurrence of combustion loss phenomena (deriving from an excessive weakening of the air/fuel mixture) to the torque developed by each cylinder, for example by utilising the speed of rotation of the crank shaft as an input. Also documents WO-A-92/10733 and US-A-5 200 899 describe methods of detecting misfires by correlating the occurence of combustion loss phenomena to the torque developed by each cylinder.

As far as this is concerned earlier European patent application EP-A-0 408 518 fits into the main thread of research documented by Italian patents 1 155 709, 1 180 045, 1 188 153, 1 219 341 and 1 203 578 which describe the operating criteria for a dynamic torque-measuring apparatus (MDC), that is to say a device which, in the case of a heat engine, taken here as an exemplary application, directly provides:

i) -- the variation of the useful torque Cu as a function of the speed of rotation by means of a test during rapid acceleration;

ii) -- the variation of the resistant torque Cr as a function of the speed of rotation; by means of a test during deceleration with the ignition of a petrol engine turned off and with the fuel of a diesel engine switched off,

The principle utilised for the operation of the dynamic torque measuring apparatus (a principle to which the present invention also will relate) is based on the equation for dynamic equilibrium of the torque acting on a rotating mass.

In the case of a heat engine two cases can be distinguished corresponding to the two types of test just described:

1- in acceleration, when the generated torque Ci, the resistant torque Cr and the inertial torque $I * \dot{\omega}_{acc}$, all act, the equation for dynamic equilibrium:

$$Cu = Ci - Cr = I * \dot{\omega}_{acc}$$

shows that from the measurement of $\dot{\omega}_{acc}$ it is possible to get back immediately to Cu.

2- in deceleration, with the motor turned off, when the resistant torque Cr and the inertial torque $I * \dot{\omega}_{dec}$ act, the equation of dynamic equilibrium:

$$Cr = I * \dot{\omega}_{dec}$$

shows that from the measurement of $\dot{\omega}_{dec}$ it is possible to get back immediately to Cr. Therefore the problem is that of measuring the acceleration.

The rotation signal provided by a phonic wheel or by an encoder is processed and differentiated to obtain the velocity and acceleration information. The two signals ω and $\dot{\omega}$ are respectively applied to the x and y inputs of a sufficiently fast plotter, which draws the two characteristics of useful torque and resistant torque in real time. It is to be noted that from the diagram produced by the dynamic torque measurement apparatus in the manner described it is possible to obtain, by rapid detections or calculations, several other quantities characteristic of the mechanism under test:

- the torque, indicated Ci, obtainable of the sum of Cu and Cr;
- the organic yield "uMDC" according to the expression :

$$uMDC = Cu / (Cu + Cr)$$

immediately calculable by using the ratio between the vertical segment of the diagram which represents Cu and that which represents the distance between the two characteristics Cu and Cr;

- the useful power $Pu = Cu * \omega$ obtainable by using the product of the ordinate and the corresponding abscissa;
- the power, indicated $Pi = Ci * \omega$ obtainable by using the product of Cu + Cr and the corresponding abscissa.

The dynamic measurement of torque applied to reciprocating engines opens a series of possibilities for analysis which corresponds to different apparatus.

To define briefly the characteristics of this family of detectors it is convenient to review the basic theory of dynamic measurement apparatus by utilising images from the description of the phenomena by means of the theorem of kinetic energy rather than the first law of dynamics.

We consider an engine in free acceleration. It is characterised by a moment of inertia I and by an angular velocity ω.

If we call the kinetic energy E and use A for the angle lying between two points (n, n-1) between which we measure the kinetic energy, and finally if we indicate the drive torque with C, we can write that the work done in the angle A has a value A * C.

In the same way the difference in the kinetic energies at the ends of this angle has the same value, that is to say:

$$A * C = E_2 - E_1 = ½ * I * (\omega_2^2 - \omega_1^2)$$

this signifies that for a certain mean angular velocity ω_m, a certain angle and a certain moment of inertia, the torque is directly calculated by the difference in the measured velocity at the two points considered and that the work done in the angle A is measured by the product of the mean velocity for the moment of inertia, and the velocity increment.

The equations which govern the operation of the system described above are correct if referred to inertial axes. In fact, with pick ups fixed to the engine crankcase it is only possible to measure relative velocity between the flywheel and the crankcase, which introduces a systematic error into the detection. This error can be eliminated or contained

but by different methods.

The vibrational noise due to the movement of the crankcase, induced by the engine itself, has a period 4π. Thus, by taking an angle of 4π as a basis for measurement of ω it is possible to cancel this disadvantage.

The elimination of the error due to vibrations is obtained by subtracting the resistant torque from the value of the useful torque for each cylinder.

The indicated torque, which is the most significant quantity since all the anomalies relating to combustion are related to it , is thus a reliable measurement.

For this, by calculating the resistant torque, which is free from vibrational error, one can, from the indicated torque for each cylinder, derive the useful torque with the vibrational error taken out.

The error due to imprecision in detection of magnetic references can be compensated using the same technique as previously explained.

The error, in fact, could be repeated in the same way both in acceleration and in deceleration and therefore the calculation of the indicated torque would eliminate it.

For a detailed description of the techniques for correction/elimination of the errors and disturbances (perturbations) mentioned above (which can advantageously be utilised within the ambit of the present invention) reference can usefully be made to the description in Italian patent 1 180 045. This is particularly valid in the presence of possible differences in compression, which could alter the results and also for indicating a possible angular error in the positioning of the detection notches on the engine flywheel. This latter is due to small differences in the positioning of the notches (in this case four at 90° from one another) present on the flywheel fitted to the crank shaft. The angular error can be found by observing the variation of the resistant torque cylinder by cylinder, which is assumed to be symmetrical.

The disparity between the cylinders falls as the speed of the engine varies, thereby confirming the presence of a geometric dissimetry. By introducing suitable corrections into the calculation of the accelerations it is therefore possible to reduce the incidence of this error.

This correction makes it possible to obtain the minimum disparity between the torques of the four cylinders, thereby guaranteeing a greater precision in the measurement.

Objects and summary of the invention

The present invention therefore has as its object the exploitation of a process and an improved system for detecting loss-of-combustion events (misfires) in internal combustion engines able to satisfy a set of requirements in an optimum way, among which can first be mentioned obtaining precise and reliable results and the possibility of implementation with simple processor means which allow the system to be mounted on board motor vehicles in particular motor cars in current production, as normal mass produced equipment.

According to the present invention this object is achieved by a process and a device having the characteristics set out in the following claims.

In summary, the invention is based on a recognition of the fact that the identification of algorithms for detecting misfires based on the methodology of dynamic torque measurement described hereinabove also allows diagnosis of misfiring to be safely made with the motor car in motion.

An important study has ascertained the influence of the conditions of use of the car on the signal measured by the dynamic measurement apparatus (the indicated torque) to which misfiring is related. If the motor is just operating in free acceleration (vehicle stationary and gear box in neutral) the moment of inertia (I) to be considered is that of the flywheel. If the propulsion unit is working normally (on the road) the moment of inertia which the system sees could depend on the coupling between the motor and the vehicle via the clutch.

In this connection experiments have been conducted in the following way:

- several measurements were taken of the dynamic torque in free acceleration (vehicle stationary and gear box in neutral);
- several detections were made in transit with the vehicle in movement on a flat road, with different gear ratios and engine conditions;
- during each test at least one misfire was caused artificially;
- the amplitude of the measured signal (indicated torque) for the cylinder which precedes that in which the misfire was generated was compared in the various test conditions.

Analysis of the results has made it apparent that the amplitude of the measured indicated torque signal, in the presence of a misfire, is independent of the working conditions of the vehicle (no-load or under load).

This indicates that the flywheel of the engine behaves as if the clutch were disconnected.

This conclusion was reached by comparing, for example in the case of a four cylinder engine, the indicated torque in cylinder number 2 measured, during each test, in the instant preceding the generation of the misfire in cylinder

number 1.

In particular, measurements in free acceleration and the most significant measurements made on the road in second and fifth gear at mid and high engine revolutions were examined.

Processing of the data shows that the values of indicated torque on cylinder number 2 both under load and with no load coincide.

This is to say that the moment of inertia to be considered, for all operating conditions of the vehicle, is always the same.

This result has made it possible to look for an algorithm for detecting loss of combustion (misfires) independently of the conditions of use of the vehicle.

Detailed description of the invention

The invention will now be described purely by way of non-limitative example, with reference to the attached drawings, in which:

- Figure 1 illustrates in the form of a block diagram, the structure of a system for the detection of misfires in an internal combustion engine, and
  Figures 2 to 15 illustrate, in diagrammatic form, various examples of embodiments of the process according to the invention.

In Figure 1 the reference numeral 1 generally indicates the system for detecting misfires which can be mounted on board a motor vehicle such as an automobile V.

The system is intended to be associated with an internal combustion engine M which drives the vehicle and the misfires of which are to be detected .

In the specific case the experimental data to which Figures 2 to 15 relate were derived from a vehicle V constituted by a Lancia Dedra 2000 CAT motor car equipped with electronic ignition and injection unit K model IAW O4J (produced by Weber) by fitting to the existing electrical connections between this and the engine M a system of connection (for example an electrical T-shaped connector) indicated with the reference letter T, for taking off signals relating to the phase of the crankshaft (PHASE) , to the top dead centre point (TDC) of the cylinders, and to the duration of fuel injection (ET) in the cylinders themselves. These signals are sent to a data acquisition card AC1 with a view to sending it via an RS232 interface line to a processor unit P such as a microprocessor or equivalent processor.

The processor unit is programmed (in a known way) so as to be able to generate the value of the indicated torque (C) relating to each cylinder starting from the information relating to the speed of rotation of the engine M.

All this is according to criteria widely known per se, which are those indicated hereinabove in relation to Italian patents 1 155 709, 1 180 045, 1 188 153, 1 219 341, 1 203 578 and in relation to European patent application EP-A-O 408 518. In particular, in the currently preferred embodiment, the indicated torque signal C is calculated according to criteria described in detail in Italian patent 1 180 045. Naturally, taking account of the fact that in the case of the present invention, the detection is made with the vehicle V under load (in traction) so that the indication of possible misfire phenomena (which is usually achieved by the effect of a display controlled by the unit P on a display D visible to the driver - typically a warning lamp or a similar indicator) is achieved in a continuous manner during the running of the vehicle.

In general, the processor unit P detects the indicated torque value for all the cylinders of the engine M, seen as a sequence of values C_i, where i identifies the general or i^{th} real or missing combustion phenomenon. The processor unit P is therefore able (according to known criteria reducible to a programming thereof which can easily be put into effect by one skilled in the art) to perform manipulation operations, in particular to obtain the difference between the detected values of C_i for different combustions.

In particular, in the embodiment of the invention currently preferred, the unit P is programmed in such a way as to be able to implement three different algorithms on the values C_i (individually and/or in combination) defined as follows:

- half-cycle algorithm
- double-cycle algorithm
- single-cycle algorithm

Half cycle algorithm

The procedure to follow in order to identify misfires requires:

- processing velocity information in such a way as to derive the value of the indicated torque (C) relating to the

cylinder under examination in the terms set out hereinabove;

- reading the injection duration (ET) actuated by the central control unit, again on the same cylinder.

Therefore, the process according to the invention (in all its various embodiments illustrated here) makes it possible to detect the indicated torque value for each expected combustion (therefore both if the combustion has taken place and if it is missing) the indicated torque value thereby generating a sequence of values ..., C_i,....

The half-cycle recognition algorithm, which we will indicate D_i, utilises the difference between C_i (relating to the "i^{th}" combustion) and C_{i-1} (relating to the "(i-1)"th combustion):

$$D_i = C_i - C_{i-1}$$

The term half-cycle makes reference to the fact that comparisons are made of the torques measured on consecutive cylinders in order of firing, that is to say each half-revolution of the engine (or 180°) for a four cylinder engine.

In the event of a single misfire, Figure 2 a) and b), D_i has a negative peak followed immediately by a positive peak D_{i+1}.

The identification of an individual misfire requires, initially, the application of the half-cycle algorithm to calculate the peak-to-peak of the PPl_i signal in the instant "i" (figure 3) which is equivalent to looking for the beginning and the end of the individual misfire:

$$Pln_i = C_i - C_{i-1} = D_i$$

$$Plp_i = C_{i+1} - C_i = D_{i+1}$$

$$PP1_i = Plp_i - Pln_i$$

where:

Pln = negative peak (beginning of misfire)
Plp = positive peak (end of misfire)
PPl = peak to peak of the half-cycle algorithm

After determination of the peak-to-peak of the signal PPl_i it is necessary to define a comparison threshold which is essential for the identification of the individual misfire.

The comparison threshold must be related to the expected indicated torque (Ca) of Figure 4b) which is proportional, to a good approximation, to the injection duration (ET), controlled at that instant by the central control unit:

$$Ca = K * ET$$

where:

K is calculable with good precision as the ratio between the maximum value of the mean indicated torque of the four cylinders (Cmax) of Figure 4a) and the maximum duration of the injection time (ET max) with the motor at full power.

In practice changing the operating conditions of the engine will involve the variation of Ca.

It thus appears evident that the comparison threshold to be utilised for detection of individual misfires must be related to the expected torque and calculated as:

$$\text{comparison threshold} = c * K * ET$$

where:

c = a coefficient which takes account of possible perturbations.

In the presence of a single misfire, if the concept of expected torque is applied to the half-cycle algorithm for the calculation of PPl_i, one gets that:

$$PPI_i = 2 * K * ET_i$$

in fact, by considering $C_i = 0$, one can say that:

$$c_{i+1} = K * ET_{i-1}$$

$$c_{i+1} = K * ET_{i+1}$$

consequently:

$$PIn_i = C_i - C_{i-1} = -K * ET_{i-1}$$

$$PIp_i = C_{i+1} - C_i = K * ET_{i+1}$$

for which if $ET_i = ET_{i+1}$, one obtains that:

$$PP1_i = K * ET_i - (-K * ET_i) = 2 * K * ET_i$$

The identification of the individual misfire is determined by evaluating the difference between PPI_i (dependent on the measured torque) and the comparison threshold (dependent on the expected torque):

$$PPI_i > cl * ET_i * K$$

where:

$ET_i =$ the injection duration relating to the i^{th} cylinder
cl = a suitable value.

The algorithm identified for detecting the loss of combustion maintains its efficacy in all operating conditions of the engine in which ET_i is greater than 0.

If, for example, we are in the presence of the CUT-OFF strategy (exclusion of the introduction of fuel when the accelerator peddle is released) with $ET_i = 0$, the application of the half-cycle algorithm would cause the indication of a misfire which in reality does not exist.

To resolve this critical state it is necessary to perform a preliminary test on the injection duration ET_i, which prevents the application of the algorithm for detecting misfires. In practice, if:

$$ET_i < ETmin$$

where:

ETmin = the value of the injection duration relating to the slow running or slightly faster condition of the engine (in our case ETmin = 4ms was used)

the test on the half cycle algorithm does not have to be made.

This arrangement serves:

- to avoid false recognitions when in CUT-OFF mode, in that a misfire indicated in this condition is indubitably an error;
- to prevent the identification of misfires in those situations (such as, for example, slow running) in which the detection is of low significance.

The half-cycle algorithm has been extensively tested from an experimental point of view. The tests related to various situations of use of the vehicle:

- flat or bumpy road
- in motion or choked at mid and high engine speeds
- with or without gear changes

During all the tests a misfire was always caused in cylinder number 1 every five engine cycles.

The generation of these latter was effected with the same central control unit K with modified software. This "misfiring generator SW" makes it possible to define:

- number of misfires to generate;
- the cylinder(s) on which to act;
- the instants in which to cause the misfires.

The tests conducted are illustrated by Figures 5 to 7 which show, as a function of time t (or of engine angle, which is equivalent):

- half-cycle test result (shown in continuous dark line);
- the comparison threshold (with continuous light line);
- the position of the generated misfires (each of which is indicated with a circle);
- the position of the misfires detected by the recognition algorithm (each identified misfire is represented by an arrow).

Figure 5 shows a measurement taken by driving the vehicle at high speed on an uneven road, with the engine put into neutral and maintained at 3000rpm to permit the acquisition of a greater quantity of data.

This test serves to verify the effect of the uneven ground on the capacity of the algorithm to discriminate possible disturbances in the signal, due to the asperities of the road, from deliberate misfires.

As can be seen, all the misfires were detected, thereby demonstrating a high level of rejection, by the half-cycle algorithm, of measurement noise generated by the road. During measurement, partial misfires generated by the engine appeared, which the algorithm correctly rejected.

Figure 6 shows a measurement taken in motion on the same section of road in second gear from 2800 to 4500 rpm.

The misfires are well discriminated notwithstanding the measurement noise from the road added to the oscillations of the transmission.

Figure 7 confirms the reliability of the algorithm even in the presence of gear changes. Substantially similar results were obtained in the case of standard operation of the vehicle travelling on a flat road in 4th gear from 2800 to 4500 rpm.

It can be seen that the half-cycle (algorithm) always intervenes up to the moment of the gear change. At this instant the motor begins to decelerate and the injection duration (ET) reduces or is cancelled entirely by the operation of the CUT-OFF strategy. This situation is identified by the monitoring of the measured injection duration, which excludes the algorithm from the test to detect misfires when ET becomes less than ETmin (equal to 4ms).

In particular conditions, for example for detection performed on a flat road in first gear, with the motor running at around 5500 rpm it happens that the considerable noise in the signal starts to be so great that it does not permit even visual discrimination of generated misfires. Likewise the half-cycle algorithm is not able to discriminate misfires correctly from the measurement noise.

Consequently, therefore, the algorithm is able to respond positively to all the standard use situations of the vehicle (flat road, rough road, gear changes), and the cylinder in which the misfire was detected is identified securely. In the most critical conditions (high engine speed and low load) where the signal-to-noise ratio is higher, the algorithm can present disadvantages, which suggests adding a further algorithm to the half-cycle algorithm (which will be denominated double-cycle) to recognise misfires even in the most serious situations.

Double-cycle algorithm

The uncertainties of the half-cycle algorithm in correctly detecting misfires were recognised in cases in which the motor works at high revolutions and low loads. In fact, in these situations, the difficulties in detection are due principally to:

- the increase in the measurement noise due to the movement of the engine block;
- the increase in the combustion dissymmetries between the various cylinders.

Taking into consideration these indications, the double-cycle algorithm, indicated D_i, was identified, which utilises the differences between C_i(torque relating to the combustion "i") and C_{i-4} (torque relating to the combustion "i-4"):

$$D_i = C_i - C_{i-4}$$

The term double-cycle makes reference to the fact that comparison is made between the torques measured on the same cylinder, that is to say every two engine revolutions (or 720°).

In the case of individual misfires (Figure 8 a) and b)) the output D_i always shows a negative peak immediately followed by a positive peak D_{i+1}.

The comparison of a cylinder with itself produces significant advantages such as:

- the significant reduction of measurement noise;
- elimination of systematic errors due to the dissymmetries of combustion between cylinders.

The application of the double-cycle algorithm is identical to that of the half-cycle algorithm. The peak-to-peak of the signal at instant "i" is calculated to give $PP4_i$:

$$P4n_i = C_i - C_{i-4} = D_i$$

$$P4p_i = C_{i+4} - C_i = D_{i+1}$$

$$PP4_i = P4p_i - P4n_i$$

where:

P4n = negative peak (beginning of misfire)
P4p = positive peak (end of misfire)
PP4 = peak-to-peak of the double-cycle algorithm.

The identification of individual misfires (Figure 9) takes place by comparing $PP4_i$ with the comparison threshold:

$$PP4_i > c4 * K * ET_i$$

The low level of noise present in this situation makes it possible to utilise a suitable value as the value of c4.

It is necessary to note that even for the double-cycle algorithm the monitoring of the injection duration, introduced for the half-cycle algorithm must be utilised.

The double-cycle algorithm was validated by performing several experimental tests in the working conditions of the engine which put the half-cycle algorithm in difficulties. During each individual test one misfire was generated in cylinder number 1 every five engine cycles. The most significant measurements were made on a flat road in first gear with the engine choked around 5500rpm (Figure 10) and intransient contitions from 5000 to 5600rpm (Figure 11).

The quantities represented in the drawing are:

- the output signal from the double-cycle algorithm (displayed as a continuous black line);
- the comparison threshold (a continuous light line);
- the positions of the generated misfires (each of which is indicated with a circle);
- the positions of the misfires detected by the recognition algorithm (each identified misfire is represented by an arrow).

The figures clearly show how,with the operation of the double-cycle algorithm, it is possible to detect (even visually) which are the deliberate misfires. The noise of the signal, present in even the half-cycle signal, is significantly reduced thereby allowing an easy identification of the misfires which occur. It is noted that the half-cycle algorithm loses its efficacy with an increase in the engine speed beyond 5000 rpm in that the signal-to-noise ratio starts to get worse. The application of the double-cycle algorithm (Figures 10, 11) allows the level of the noise present to be reduced, thereby

permitting detection of the occurrence of misfires.

Single-cycle algorithm

The two methods described for the detection of misfires still have some problems:

- the half-cycle algorithm does not recognise two consecutive misfires (that is to say on two sequential cylinders in the firing order);
- the double-cycle algorithm does not identify a permanently inactive cylinder.

To obviate these difficulties a further algorithm has been identified to put alongside the others, in which the value of D_i is calculated as the difference between C_i (torque relative to the i^{th} combustion) and C_{i-2} (the torque relating to combustion "i-2"):

$$D_i = C_i - C_{i-2}$$

This algorithm has been indicated with the term "single cycle" (Figures 12 a) and b)), with reference to the fact that the torques measured on one cylinder and on the opposite cylinder one engine revolution later (or 360°) are compared.

For the application of the single-cycle algorithm the peak-to-peak of the signal at the instant "i" is also calculated to give $PP2_i$:

$$P2n_i = C_i - C_{i-2} = D_i$$

$$P2p_i = C_{i+2} - C_i = D_{i+1}$$

$$PP2_i = P2p_i - P2n_i$$

where:

P2n = negative peak (beginning of misfire)
P2p = positive peak (end of misfire)
PP2 = peak-to-peak of the single cycle algorithm.

Identification of an individual misfire (Figure 13) is, in this case, too, achieved by testing $PP2_i$ against the comparison threshold:

$$PP2_i > c2 * K * ET_i$$

The single-cycle algorithm has a greater noise level than the double-cycle algorithm so that it is necessary to use a suitable value of c2 where appropriate. For this algorithm, too, the threshold is proportional to the injection duration.

Experimental tests on the single-cycle algorithm have been performed in conditions in which the two main algorithms are not satisfactory.

Figure 14 shows a measurement taken on a flat road in second gear at 4000 rpm with the injection of cylinder number 1 interrupted during the whole of the test.

In this case, where the double-cycle algorithm gets into difficulties, the single-cycle algorithm intervenes thereby permitting a secure and correct detection of the misfires.

Figure 15 shows a measurement taken on a flat road travelling in 4th gear from 2500 to 3500 rpm with misfires generated every five engines cycles on cylinder number 1 and on cylinder number 3.

This particular measurement condition makes it possible to demonstrate the validity of the single-cycle algorithm in identifying two consecutive misfires, thereby confirming the ineffectiveness of the half-cycle algorithm in this situation.

Applications of the recognition algorithms

The search for a method to identify misfires has lead to the identification and validation of three algorithms.

- half-cycle: for situations of standard use of the vehicle (low motor speed, flat or bumpy road, in motion, choked or changing gear);
- double-cycle: for more critical conditions of use (high engine speed, low load...);
- single-cycle: for operation in cases in which the half and double-cycle fail.

In reality it is more correct to speak of two "pairs of algorithms" in that the single-cycle algorithm is allied to both the half- and double-cycle algorithm. In this way two separate "configurations" are obtained from the working conditions of the engine:

- configuration 1 (standard conditions)
  half-cycle and single-cycle
- configuration 2 (critical conditions)
  double-cycle and single-cycle

It is apparent that the effectiveness of the detection of misfires in all working situations with the vehicle in motion is determined by the integration of the two configurations into a single structure.

In order to do this it is necessary to identify a process which establishes when to change the "pair of algorithms" if the operating conditions of the engine change.

The method identified takes into consideration:

- the speed of the engine, detected at the instant in which the measurement MDC/CC is performed and an engine speed threshold (Velomax) which allows the tests to be activated on one of the two configurations.

Velomax is identified in an experiemental way, for example with a dynamic torque detection cycle in free acceleration (see, for example, Italian patent 1 180 045) and is detected at the point at which the dissymmetries of combustion between the various cylinders and the vibrational noise increase the measured signal noise. An experimental value of Velomax which has been shown to be particularly advantageous is situated around 4500 rpm.

This means that, by the nature of the "two pairs of algorithms":

- if the motor speed is less than Velomax we are in configuration 1 test conditions:
  half-cycle algorithm:

$$PPI_i > cl * K * ET_i$$

and the single-cycle algorithm, which is able to detect the presence of two consecutive misfires:

$$PP2_i > c2 * K * ET_i$$

- if the motor speed is greater than or equal to Velomax, then configuration 2 is used for the test: double-cycle algorithm:

$$PP4_i > c4 * K * ET_i$$

and the single-cycle algorithm, if we are in the presence of an inactive cylinder or of at least two consecutive misfires again in the same cylinder:

$$PP2_i > c2 * K * ET_i$$

This procedure allows integration of the algorithms for the detection of the misfires in-to a single structure, allowing the changeover of the test configuration on the basis of the variation of engine speed.

The integrated algorithms for detection of misfires have been validated with a series of experimental tests made in different working conditions of the vehicle and the engine. The tests were conducted with the same measurement equipment used in the tests of the individual algorithms. Information on the tests conducted and the results obtained have been collected in two tables appearing in the following.

Table 1 records general information on the individual tests:

measurement conditions

- reference index for each test (number);
- type of terrain (off road or flat asphalt road);
- gear engaged;
- engine revolutions;
- type of test:

PP = full power with butterfly valve completely open
PZ = throttled with butterfly valve open 50%
TR = velocity transient.

Generated misfires

- cylinder(s): indicates the cylinder or cylinders in which the misfires were generated;
- rate: indicates the frequency with which generated misfires are repeated (1x1 cycle = every engine cycle, 1x5 cycles = every five engine cycles).

Table 2 records the the results obtained for each detection as:

- the reference index of the measurement;
- the number of generated misfires and the cylinder or cylinders involved (CYL1,2,3,4 = cylinder 1,2,3,4);
- the number of misfires detected by the integrated algorithms and the cylinder or cylinders involved.

Table 1

General Information			
No.	Measurement Conditions	Generated Misfires Cylinder(s)	Rate
00	Loose earth in neutral at 3000 rpm	Cylinder 1	1 x 5 cycles
01	Loose earth in neutral at 3000 rpm	Cylinders 1 & 3	1 x 5 cycles
02	Loose earth PP in second gear from 2800 to 4500 rpm	Cylinder 1	1 x 5 cycles
03	Loose earth PP in second gear from 2800 to 4500 rpm	Cylinders 1 & 3	1 x 5 cycles
04	Road, in neutral at 3000 rpm	Cylinder 1	1 x 5 cycles
05	Road, in neutral at 3000 rpm	Cylinders 1 & 3	1 x 5 cycles
06	Road, PP in second gear from 2800 to 4500 rpm	Cylinder 1	1 x 5 cycles
07	Road, PP in second gear from 2800 to 4500 rpm	Cylinders 1 & 3	1 x 5 cycles
08	Road, PZ in second gear at 3000 rpm	Cylinder 1	1 x 5 cycles
09	Road, PZ in second gear at 3000 rpm	Cyliniders 1 & 3	1 x 5 cycles
10	Road, PP in fourth gear from 2800 to 5000 rpm	Cylinder 1	1 x 5 cycles

Table 1 (continued)

General Information			
No.	Measurement Conditions	Generated Misfires Cylinder(s)	Rate
11	Road, PP in fourth gear from 2800 to 5000 rpm	Cylinders 1 & 3	1 x 5 cycles
12	Road, PZ in fourth gear at 3000 rpm	Cylinder 1	1 x 5 cycles
13	Road, PZ in fourth gear at 3000 rpm	Cylinders 1 & 3	1 x 5 cycles
14	Road, PP in fifth gear from 3800 to 4500 rpm	Cylinder 1	1 x 5 cycles
15	Road, with gear changes (i, ii, iii, iv)	Cylinder 1	1 x 1 cycle
16	Road, with gear changes (i, ii, iii, iv)	without misfiring	

Table 2

Comparison between generated and detected misfires								
GENERATED MISFIRES					DETECTED MISFIRES			
n	CILI	CIL3	CIL4	CIL2	CIL1	CIL3	CIL4	CIL2
00	20	0	0	0	20	0	0	1
01	19	19	0	0	19	19	0	0
02	20	0	0	0	20	0	0	0
03	20	20	0	0	20	20	0	0
04	17	0	0	0	17	0	0	0
05	19	18	0	0	19	18	0	0
06	20	0	0	0	20	0	0	0
07	20	20	0	0	20	20	0	0
08	20	0	0	0	20	0	0	0
09	20	20	0	0	20	20	0	0
10	17	0	0	0	17	0	0	0
11	20	20	0	0	20	20	0	0
12	20	0	0	0	20	0	0	0
13	20	20	0	0	20	20	0	0
14	20	0	0	0	20	0	0	0
15	55	0	0	0	55	0	0	0
16	0	0	0	0	0	1	0	0

The experimental validation undertaken has shown:

1 - the effectiveness of the integrated algorithms in correctly detecting the generated misfires and the cylinder or cylinders involved;

2 - the validity of the identified procedure (use of Velomax threshold) for changing the configuration of algorithms for testing upon variation of the surrounding conditions (type of ground, engine load,...).

As can be seen from Table 2 the results obtained are more than satisfactory. All the misfires generated during every individual test were identified by the integrated algorithms.

In particular cases, such as detection number 00 and number 16 the further misfires detected really existed in that they were caused by the engine.

The detection of misfires as in this latter unexpected case, confirms further the capacity of the integrated algorithms to identify the occurrence of misfires.

Notwithstanding having operated in the most critical situation for reading the angular velocity, that is with a pulley having four teeth (and therefore with a fixed angular window at 90°), no critical states were evident in the application of the methodology.

It is important to underline that if one were to have available a phonic wheel with more teeth or if one were to be able to position the references with freedom, one would have the possibility of optimising the angular basis for measurement and the phase with respect to TDC, thereby improving the misfire detection performance.

The recognition algorithms were validated both in what may be considered as normal operating conditions of the vehicle and those made artificially difficult, that is to say those which in practice would not ever occur.

The algorithms for the detection of misfires were implemented in the electronic central control unit K by modifying only the software present without any problems for the other existing functions.

Claims

1. A process for detecting misfires in an internal combustion engine (M), characterised in that it comprises the steps of:

   - detecting, for each expected combustion, the value of the indicated torque of the engine (M), generating a corresponding sequence of values (...,Ci,...),
   - generating, as a combination of at least two successive values of the said sequence, a cycle signal (Di),
   - determining a peak value ($PP1_i$; $PP4_i$; $PP2_i$) of the said cycle signal (Di),
   - determining a threshold value (Ca) corresponding to the expected torque of the engine in the presence of effective combustion, and
   - comparing the said peak value ($PP1_i$; $PP4_i$; $PP2_i$) with the said threshold value (Ca), thereby identifying a misfire when the result of the said comparison is different from the result of the comparison in the presence of regular operation of the engine (M).

2. A process according to Claim 1, characterised in that the said cycle signal (Di) is calculated as the difference between two successive values of the said sequence (Ci).

3. A process according to Claim 1 or Claim 2, characterised in that the said peak value ($PP1_i$; $PP4_i$; $PP2_i$) is determined as a peak-to-peak value of the said cycle signal (Di).

4. A process according to any preceding claim, performed on an internal combustion engine in which the injection of fuel into each cylinder takes place with a predetermined duration (ET), characterised in that the said comparison threshold is chosen as a function of the said injection duration (ET).

5. A process according to Claim 4, characterised in that the said comparison threshold (Ca) is chosen to be proportional, with a constant of proportionality, to the said injection duration (ET).

6. A process according to Claim 5, characterised in that the constant of proportionality between the comparison threshold (Ca) and the injection duration is determined as a function of the ratio between the maximum value of the mean indicated torque of the engine cylinders (M) and the maximum value of the injection duration (ETmax) with the engine (M) at full power.

7. A process according to Claim 5 or Claim 6, characterised in that it further includes the steps of detecting, during performance of the process, the value of the said injection duration (ET), and inhibiting the detection of misfires when the said injection duration falls below a minimum value (ETmin).

8. A process according to Claim 5, characterised in that it further includes the step of modulating the value of the said constant of proportionality with a further constant of proportionality in dependence on the choice of the said two successive values in the sequence.

9. A process according to any preceding claim, characterised in that, starting from the said at least two successive values of the said sequence, there is generated at least one of the three following cycle signals (D1):

   - a first cycle signal in which two said successive values of the said sequence are chosen as values corresponding to consecutive expected combustions on the cylinders seen in firing order (C_i ; C_{i-1}),
   - a second cycle signal, in which the said successive values of the said sequence are chosen as corresponding

to two consecutive expected combustions on the same cylinder (C_i-C_{i-4});

- a third cycle signal in which the said two successive values of the said sequence are chosen as corresponding to expected consecutive combustions on one cylinder and on the opposite cylinder one engine revolution later (C_i-C_{i-2}).

10. A process according to Claim 8 and Claim 9, characterised in that the said further constant of proportionality is chosen in a manner which is different according as the said first, the said second or the said third cycle signal is determined.

11. A process according to Claim 10, characterised in that values for the said further constant of proportionality are chosen according to whether the said first, the said second or the said third cycle signal is determined, which stand in relation to one another in relative ratios characteristic of each type of engine.

12. A process according to Claim 9, characterised in that it includes the steps of simultaneously generating at least two of the said first, said second and said third cycle signal, determining a respective peak value for the said at least two cycle signals generated by comparing the peak values thus generated with respective threshold values, thereby simultaneously effecting two misfire detection operations.

13. A process according to any of Claims from 9 to 12, characterised in that it includes the steps of detecting the speed of rotation of the engine (M), then comparing the speed of rotation of the engine with a reference threshold (Velomax), then generating a first and a second pair respectively, of said cycle signals according as the speed of rotation of the engine is less or greater than the said reference threshold.

14. A process according to Claim 13, characterised in that the said reference threshold (Velomax) is chosen to be in the region of about 4500 revolutions per minute.

15. A process according to Claim 13 or Claim 14, characterised in that the first pair of cycle signals comprises the said first and the said second cycle signal whilst the said second pair of cycle signals comprises the said second and the said third cycle signal.

16. A process according to any preceding claim, characterised in that it is performed with the said engine (M) mounted on a vehicle, with the engine (M) itself operating whilst the vehicle is travelling.

17. A system for performing the process of any of Claims 1 to 15, characterised in that it comprises:

- first sensor means (T,K) for detecting the speed and the instantaneous phase of rotation of the said engine (M), the passage of the cylinders through the top dead centre position (TDC) and the duration of fuel injection into the cylinders of the engine itself (ET),
- processor means (AC1,P) programmed to determine:
  - the said sequence of values of indicated torque (C_i) from the engine (M) speed signal,
  - the said cycle signal (D_i) from the said sequence of values of indicated torque (C_i),
  - the said peak value ($PP1_i$; $PP4_i$; $PP2_i$) from the said cycle signal (D),
  - the said comparison threshold value (Ca),
  - comparing the said peak value ($PP1_i$; $PP4_i$; $PP2_i$) with the said threshold value (Ca) thereby determining, for each comparison, a corresponding result, and
  - display means (D) controlled by the said processor means (P) to present the result of the said comparisons.

18. A system according to Claim 17, characterised in that the said first sensor means generate a further signal indicative of the duration of the time interval for which fuel is injected into the engine (ET) cylinders and in that the said processor means (P) are programmed to calculate, the said comparison threshold (Ca) from the said injection duration signal (ET).

Pat ntansprüch

1. Verfahren zum Abtasten von Fehlzündungen in einem Verbrennungsmotor (M), dadurch gekennzeichnet, daß das Verfahren folgende Schritte enthält:

- Abtasten des Werts des indizierten Drehmoments des Motors (M) für jede erwartete Verbrennung, wobei eine entsprechende Folge von Werten (...,Ci,...) erzeugt wird,

- Erzeugen eines Zyklussignals (Di) als Kombination von zumindest zwei aufeinanderfolgenden Werten dieser Folge,

- Bestimmen des Spitzenwerts ($PP1_i$; $PP4_i$; $PP2_i$) des Zyklussignals (Di),

- Festlegen eines Schwellenwerts (Ca), der dem erwarteten Drehmoment des Motors beim Vorhandensein einer wirkungsvollen Verbrennung entspricht, und

- Vergleichen des Spitzenwerts ($PP1_i$; $PP4_i$; $PP2_i$) mit dem Schwellenwert (C_a), um dadurch eine Fehlzündung zu erkennen, wenn sich das Ergebnis des Vergleichs vom Ergebnis des Vergleichs bei einem normalen Betrieb des Motors (M) unterscheidet.

2. Verfahren gemäß Anspruch 1, dadurch gekennzeichnet, daß das Zyklussignal (Di) als Differenz zwischen zwei aufeinanderfolgenden Werten der Folge (Ci) berechnet wird.

3. Verfahren gemäß Anspruch 1 oder 2, dadurch gekennzeichnet, daß der Spitzenwert ($PP1_i$; $PP4_i$; $PP2_i$) als Spitze-zu-Spitze-Wert des Zyklussignals (Di) bestimmt wird.

4. Verfahren gemäß irgendeinem der bisherigen Ansprüche, wobei das Verfahren bei einem Verbrennungsmotor ausgeführt wird, bei dem die Kraftstoffeinspritzung in jeden Zylinder mit einer vorgegebenen Dauer (ET) erfolgt, dadurch gekennzeichnet, daß der Vergleichsschwellenwert als Funktion dieser Einspritzdauer (ET) gewählt wird.

5. Verfahren gemäß Anspruch 4, dadurch gekennzeichnet, daß der Vergleichsschwellenwert (Ca) so gewählt wird, daß er mit einer Proportionalitätskonstanten der Einspritzdauer (ET) proportional ist.

6. Verfahren gemäß Anspruch 5, dadurch gekennzeichnet, daß die Proportionalitätskonstante zwischen dem Vergleichsschwellenwert (Ca) und der Einspritzdauer als Funktion des Verhältnisses zwischen dem Maximalwert des mittleren indizierten Drehmoments der Motorzylinder (M) und dem Maximalwert der Einspritzdauer (ETmax) bei voller Leistung des Motors (M) festgelegt wird.

7. Verfahren gemäß Anspruch 5 oder 6, dadurch gekennzeichnet, daß das Verfahren weiters Schritte aufweist, in denen, während das Verfahren läuft, der Wert der Einspritzdauer (ET) abgetastet und die Abtastung von Fehlzündungen verhindert wird, wenn die Einspritzdauer unter einen Minimalwert (ETmin) fällt.

8. Verfahren gemäß Anspruch 5, dadurch gekennzeichnet, daß das Verfahren weiters einen Schritt aufweist, in dem der Wert der Proportionalitätskonstanten mit einer weiteren Proportionalitätskonstanten in Abhängigkeit von der Auswahl jener Werte verändert wird, die in der Folge aufeinander folgen.

9. Verfahren gemäß irgendeinem der bisherigen Ansprüche, dadurch gekennzeichnet, daß, ausgehend von den zumindest beiden aufeinander folgenden Werten der Folge, zumindest eines der drei folgenden Zyklussignale (D1) erzeugt wird:

- ein erstes Zyklussignal, bei dem die beiden aufeinander folgenden Werte der Folge als Werte gewählt werden, die aufeinanderfolgenden, erwarteten Verbrennungen in den Zylindem entsprechen, die in der Zündfolge aufeinander folgen (c_i; C_{i-1}),

- ein zweites Zyklussignal, bei dem die aufeinander folgenden Werte der Folge so gewählt werden, daß sie zwei aufeinander folgenden, erwarteten Verbrennungen im selben Zylinder (C_i - C_{i-4}) entsprechen,

- ein drittes Zyklussignal, bei dem die beiden aufeinander folgenden Werte der Folge so gewählt werden, daß sie aufeinander folgenden, erwarteten Verbrennungen in einem Zylinder und im gegenüberliegenden Zylinder eine Motorumdrehung später (c_i - C_{i-2}) entsprechen.

10. Verfahren gemäß Anspruch 8 und 9, dadurch gekennzeichnet, daß die weitere Proportionalitätskonstante auf eine Art gewählt wird, die sich von der Art unterscheidet, auf die das erste, zweite oder dritte Zyklussignal f stgelegt wird.

11. Verfahren gemäß Anspruch 10, dadurch gekennzeichnet, daß die Werte für die weitere Proportionalitätskonstante in Übereinstimmung damit gewählt werden, ob das erste, zweite oder dritte Zyklussignal festgelegt wird, die miteinander in relativen Verhältnissen einer jeden Motorenart stehen.

12. Verfahren gemäß Anspruch 9, dadurch gekennzeichnet, daß das Verfahren Schritte aufweist, in denen gleichzeitig zumindest zwei Signale des ersten, zweiten und dritten Zyklussignals erzeugt werden, ein entsprechender Spitzenwert für die zumindest zwei Zyklussignale festgelegt wird, die dadurch erzeugt werden, daß die auf diese Weise erzeugten Spitzenwerte mit entsprechenden Schwellenwerten verglichen werden, um dadurch gleichzeitig zwei Abtastvorgänge für Fehlzündungen auszuführen.

13. Verfahren gemäß irgendeinem der Ansprüche 9 bis 12, dadurch gekennzeichnet, daß das Verfahren Schritte aufweist, in denen die Drehzahl des Motors (M) abgetastet und dann die Drehzahl des Motors mit einem Bezugsschwellenwert (Velomax) verglichen wird, worauf ein erstes bzw. zweites Paar von Zyklussignalen in Übereinstimmung damit erzeugt wird, ob die Drehzahl des Motors kleiner oder größer als der Bezugsschwellenwert ist.

14. Verfahren gemäß Anspruch 13, dadurch gekennzeichnet, daß der Bezugsschwellenwert (Velomax) so gewählt wird, daß er im Bereich von etwa 4500 Umdrehungen pro Minute liegt.

15. Verfahren gemäß Anspruch 13 oder 14, dadurch gekennzeichnet, daß das erste Paar von Zyklussignalen das erste und zweite Zyklussignal enthält, während das zweite Paar von Zyklussignalen das zweite und dritte Zyklussignal enthält.

16. Verfahren gemäß irgendeinem der bisherigen Ansprüche, dadurch gekennzeichnet, daß das Verfahren mit einem Motor (M) ausgeführt wird, der in einem Fahrzeug angebracht ist, wobei der Motor (M) läuft, während das Fahrzeug fährt.

17. System, um das Verfahren gemäß irgendeinem der Ansprüche 1 bis 15 auszuführen, dadurch gekennzeichnet, daß das System enthält:

- eine erste Fühlereinrichtung (T, K), um die Drehzahl sowie die momentane Drehphase des Motors (M), den Durchgang der Zylinder durch den oberen Totpunkt (TDC) sowie die Dauer der Kraftstoffeinspritzung (ET) in die Zylinder des Motors abzutasten,

- eine Verarbeitungsstufe (AC1, P), die so programmiert ist, um festzulegen:

  - die Folge der Werte des indizierten Drehmoments (C_i) vom Drehzahlsignal des Motors (M),

  - das Zyklussignal (D_i) von der Folge von Werten des indizierten Drehmoments (C_i),

  - den Spitzenwert ($PP1_i$; $PP4_i$; $PP2_i$) des Zyklussignals (D),

  den Vergleichsschwellenwert (Ca),

  - einen Vergleich des Spitzenwerts ($PP1_i$; $PP4_i$; $PP2_i$) mit dem Schwellenwert (Ca), um dadurch für jeden Vergleich ein entsprechendes Ergebnis festzulegen, und

  - eine Anzeigeeinrichtung (D), die von der Verarbeitungsstufe (P) gesteuert wird, um das Ergebnis der Vergleiche darzustellen.

18. System gemäß Anspruch 17, dadurch gekennzeichnet, daß die erste Fühlereinrichtung ein weiters Signal erzeugt, das die Dauer jenes Zeitintervalls anzeigt, in dem Kraftstoff in die Zylinder des Motors (ET) eingespritzt wird, und daß die Verarbeitungsstufe (P) so programmiert ist, um den Vergleichsschwellenwert (Ca) vom Einspritzdauersignal (ET) zu berechnen.

R v ndications

1. Procédé de détection de ratés d'allumage dans un moteur à combustion interne (M), caractérisé en ce qu'il com-

prend les étapes consistant :

- à détecter, à chaque combustion attendue, la valeur du couple indiqué du moteur (M), générant une séquence correspondante de valeurs (..., Ci, ...),
- à générer, en tant que combinaison d'au moins deux valeurs successives de ladite séquence, un signal de cycle (Di),
- à déterminer une valeur de crête ($PP1_i$; $PP4_i$; $PP2_i$) dudit signal de cycle (Di),
- à déterminer une valeur de seuil (Ca) correspondant au couple attendu du moteur lorsque se produit une combustion effective, et
- à comparer ladite valeur de crête ($PP1_i$; $PP4_i$; $PP2_i$) à ladite valeur de seuil (Ca), identifiant, de cette façon, un raté d'allumage lorsque le résultat de ladite comparaison diffère du résultat de la comparaison faite au cours du fonctionnement normal du moteur (M).

2. Procédé selon la revendication 1, caractérisé en ce que ledit signal de cycle (Di) est calculé comme étant la différence entre deux valeurs successives de ladite séquence (Ci).

3. Procédé selon la revendication 1 ou 2, caractérisé en ce que ladite valeur de crête ($PP1_i$; $PP4_i$; $PP2_i$) est déterminé comme étant la valeur crête-à-crête dudit signal de cycle (Di).

4. Procédé selon l'une quelconque des revendications précédentes, mis en oeuvre sur un moteur à combustion interne dans lequel l'injection de carburant dans chaque cylindre se produit pendant une durée prédéterminée (ET), caractérisé en ce que ledit seuil de comparaison est choisi en fonction de ladite durée d'injection (ET).

5. Procédé selon la revendication 4, caractérisé en ce que ledit seuil de comparaison (Ca) est choisi de manière à être proportionnel, à une constante de proportionnalité près, à ladite durée d'injection (ET).

6. Procédé selon la revendication 5, caractérisé en ce que la constante de proportionnalité entre le seuil de comparaison (Ca) et la durée d'injection est déterminée en fonction du rapport entre la valeur maximale du couple indiqué moyen des cylindres du moteur (M) et la valeur maximale de la durée d'injection (ETmax), le moteur (M) tournant à plein régime.

7. Procédé selon la revendication 5 ou 6, caractérisé en ce qu'il comprend, en outre, les étapes consistant à détecter, au cours de la mise en oeuvre du procédé, la valeur de ladite durée d'injection (ET), et à inhiber la détection des ratés d'allumage lorsque ladite durée d'injection chute en deçà d'une valeur minimale (ETmin).

8. Procédé selon la revendication 5, caractérisé en ce qu'il comprend, en outre, l'étape consistant à moduler la valeur de ladite constante de proportionnalité par une autre constante de proportionnalité dépendant du choix desdites deux valeurs successives de la séquence.

9. Procédé selon l'une quelconque des revendications précédentes, caractérisé en ce que, en partant desdites au moins deux valeurs successives de ladite séquence, est généré au moins un des trois signaux de cycle (D1) suivants :

- un premier signal de cycle dans lequel deux dites valeurs successives de ladite séquence sont choisies comme valeurs correspondant à des combustions. consécutives attendues dans les cylindres considérés selon l'ordre d'allumage (C_i ; C_{i-1}),
- un second signal de cycle dans lequel lesdites valeurs successives de ladite séquence sont choisies comme correspondant à deux combustions consécutives attendues dans le même cylindre (C_i-C_{i-4}),
- un troisième signal de cycle dans lequel lesdites deux valeurs successives de ladite séquence sont choisies comme correspondant à des combustions consécutives attendues dans un premier cylindre et dans le cylindre opposé, un tour de moteur plus tard (C_i-C_{i-2}).

10. Procédé selon les revendications 8 et 9, caractérisé en ce que ladite autre constante de proportionnalité est choisie d'une manière qui diffère selon que ledit premier, ledit second ou ledit troisième signal de cycle est déterminé.

11. Procédé selon la revendication 10, caractérisé en ce que les valeurs de ladite autre constante de proportionnalité sont choisies selon que ledit premier, ledit second ou ledit troisième signal de cycle est déterminé, étant liés les uns aux autres selon des rapports relatifs qui sont caractéristiques de chaque type de moteur.

12. Procédé selon la revendication 9, caractérisé en ce qu'il comprend les étapes consistant à générer simultanément au moins deux parmi ledit premier, ledit second et ledit troisième signal de cycle, à déterminer une valeur de crête respective desdits au moins deux signaux de cycle générés en comparant les valeurs de crête ainsi générées à des valeurs de seuil respectives, à effectuer simultanément, de cette façon, deux opérations de détection de ratés d'allumage.

13. Procédé selon l'une quelconque des revendications 9 à 12, caractérisé en ce qu'il comprend les étapes consistant à détecter la vitesse de rotation du moteur (M), puis à comparer la vitesse de rotation du moteur à un seuil de référence (Velomax), puis à générer une première et une seconde paire respectivement, desdits signaux de cycle selon que la vitesse de rotation du moteur est inférieure ou supérieure audit seuil de référence.

14. Procédé selon la revendication 13, caractérisé en ce que ledit seuil de référence (Velomax) est choisi pour se situer dans la plage avoisinant les 4500 tours par minute environ.

15. Procédé selon la revendication 13 ou 14, caractérisé en ce que la première paire de signaux de cycle comprend ledit premier et ledit second signal de cycle tandis que ladite seconde paire de signaux de cycle comprend ledit second et ledit troisième signal de cycle.

16. Procédé selon l'une quelconque des revendications précédentes, caractérisé en ce qu'il est mis en oeuvre lorsque ledit moteur (M) est monté sur un véhicule, le moteur (M) lui-même fonctionnant alors que le véhicule se déplace.

17. Système pour mettre en oeuvre le procédé selon l'une quelconque des revendications 1 à 15, caractérisé en ce qu'il comprend :

- des premiers moyens à capteurs (T, K) destinés à détecter la vitesse et la phase de rotation instantanée dudit moteur (M), le passage des cylindres par le point mort haut (TDC) et la durée d'injection de carburant dans les cylindres du moteur lui-même (ET),
- des moyens à processeurs (AC1, P) programmés pour déterminer :
  - ladite séquence de valeurs du couple indiqué (Ci) à partir du signal de la vitesse du moteur (M),
  - ledit signal de cycle (D_i) à partir de ladite séquence de valeurs du couple indiqué (C_i),
  - ladite valeur de crête ($PP1_i$; $PP4_i$; $PP2_i$) à partir dudit signal de cycle (D),
  - ladite valeur de seuil de comparaison (Ca),
  - pour comparer ladite valeur de crête ($PP1_i$; $PP4_i$; $PP2_i$) à ladite valeur de seuil (Ca), pour déterminer, de cette façon, à chaque comparaison, un résultat correspondant, et
  - des moyens d'affichage (D) commandés par lesdits moyens à processeurs (P) et destinés à présenter le résultat desdites comparaisons.

18. Système selon le ravendication 17, caractérisé en ce que lesdits premiers moyens à capteurs génèrent un signal supplémentaire indicatif de la durée de l'intervalle de temps pendant lequel du carburant est injecté dans les cylindres du moteur (ET), et en ce que lesdits moyens à processeurs (P) sont programmés pour calculer ledit seuil de comparaison (Ca) à partir dudit signal de durée d'injection (ET).

FIG. 1

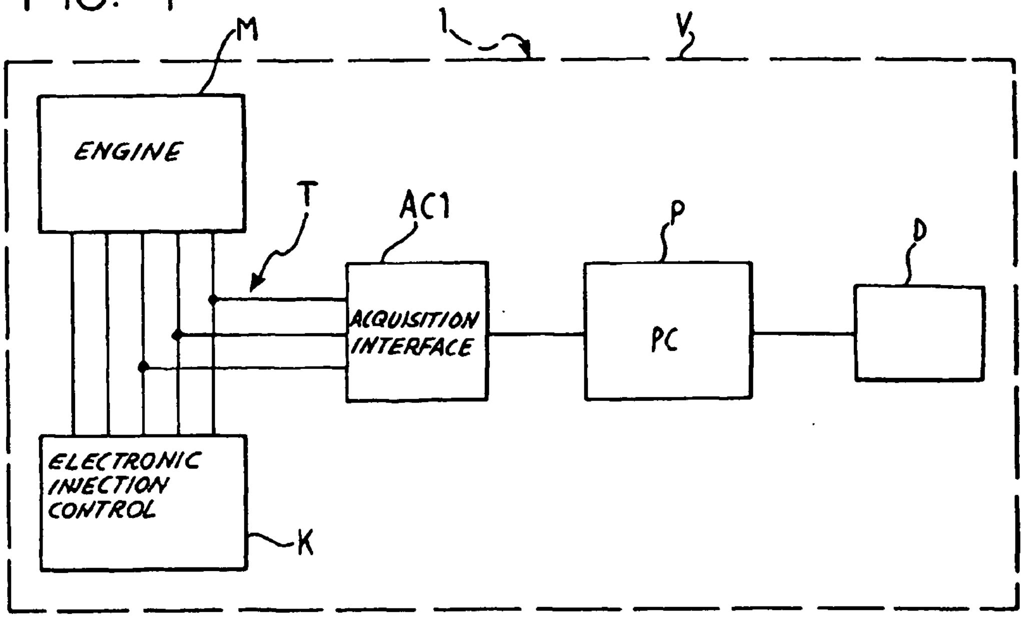

M
1
V
ENGINE
T
AC1
P
D
ACQUISITION INTERFACE
PC
ELECTRONIC INJECTION CONTROL
K

FIG. 2

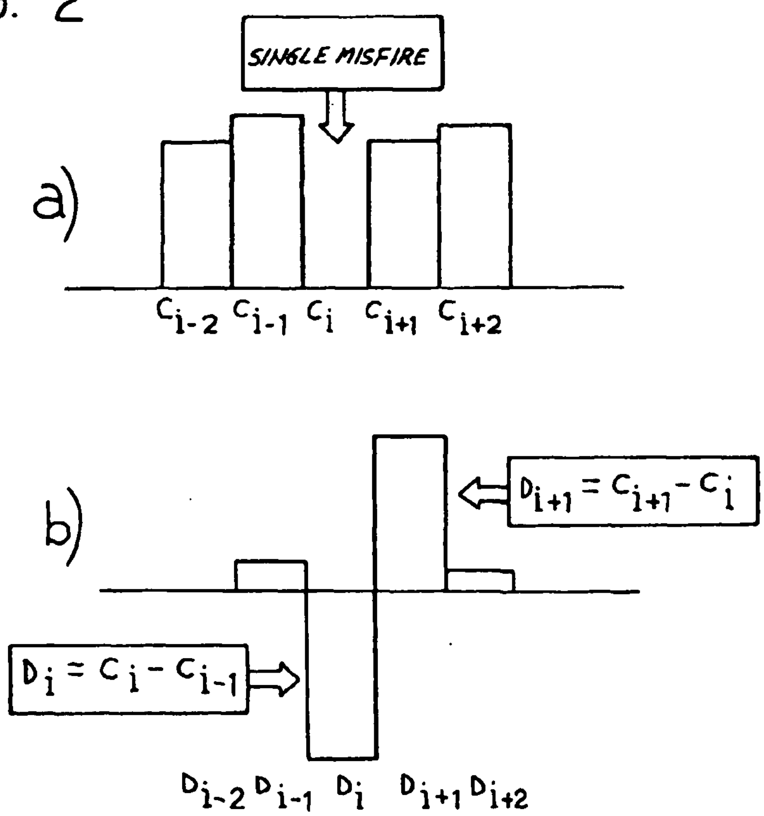

SINGLE MISFIRE
a)
C_{i-2} C_{i-1} C_i C_{i+1} C_{i+2}
b)
$D_{i+1} = C_{i+1} - C_i$
$D_i = C_i - C_{i-1}$
D_{i-2} D_{i-1} D_i D_{i+1} D_{i+2}

FIG. 3

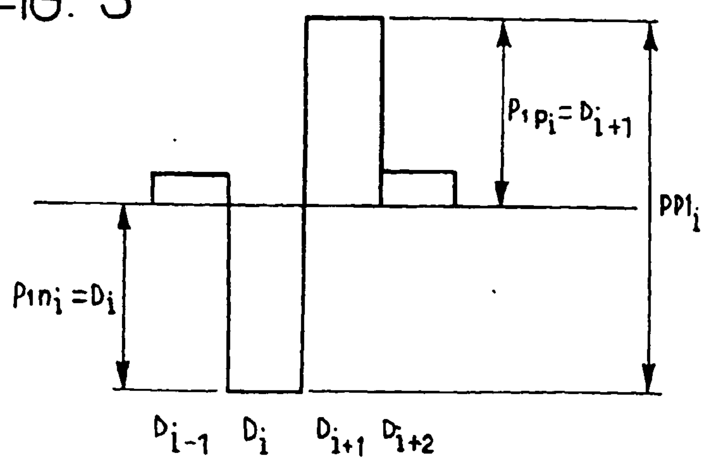

P1pi = Di+1
PP1i
P1ni = Di
Di-1
Di
Di+1
Di+2

FIG. 4

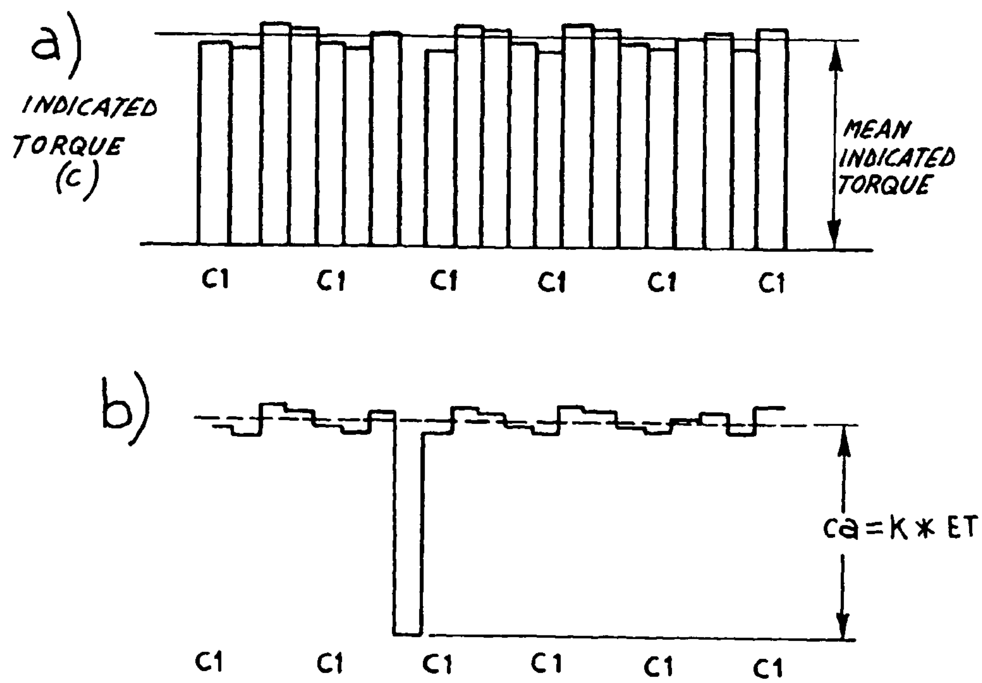
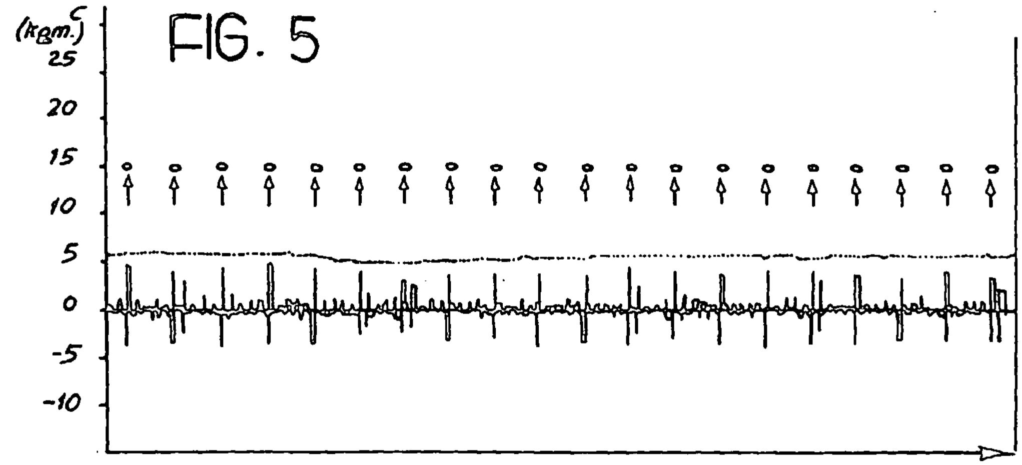
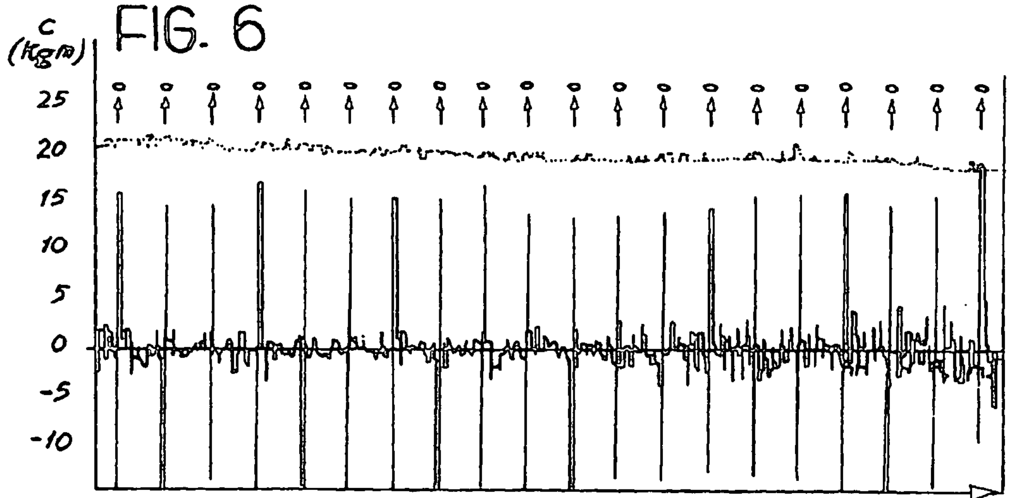

a)
INDICATED TORQUE (C)
MEAN INDICATED TORQUE
C1 C1 C1 C1 C1 C1
b)
Ca = K * ET
C1 C1 C1 C1 C1 C1

FIG. 5



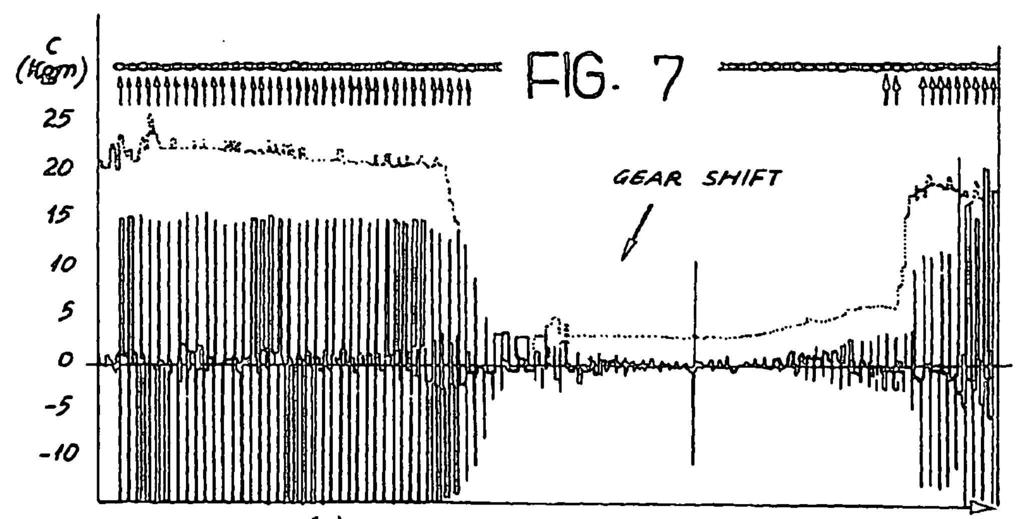
(o) → POSITIONS OF MISFIRES GENERATED
(↑) → POSITIONS OF MISFIRES DETECTED

FIG. 6



(o) → POSITIONS OF MISFIRES GENERATED

FIG. 7



(o) → POSITIONS OF MISFIRES GENERATED
(↑) → POSITIONS OF MISFIRES DETECTED

FIG. 8

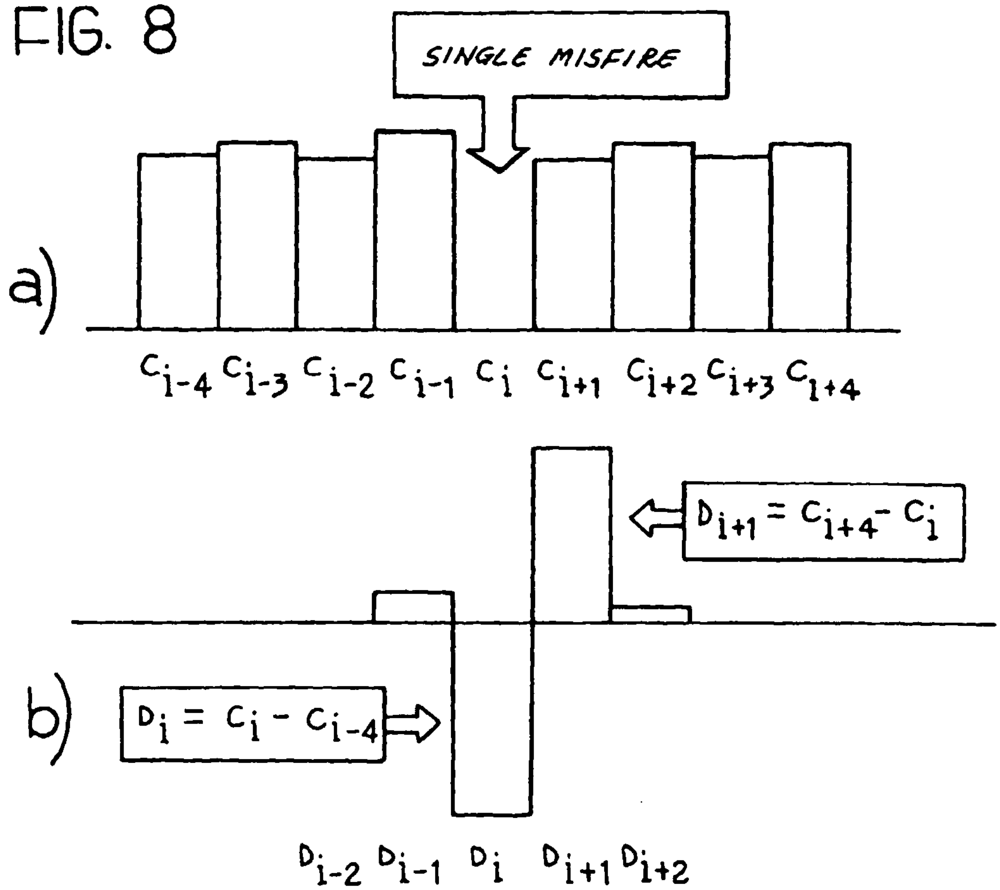

SINGLE MISFIRE
a)
C_{i-4} C_{i-3} C_{i-2} C_{i-1} C_i C_{i+1} C_{i+2} C_{i+3} C_{i+4}
$D_{i+1} = C_{i+4} - C_i$
b)
$D_i = C_i - C_{i-4}$
D_{i-2} D_{i-1} D_i D_{i+1} D_{i+2}

FIG. 9

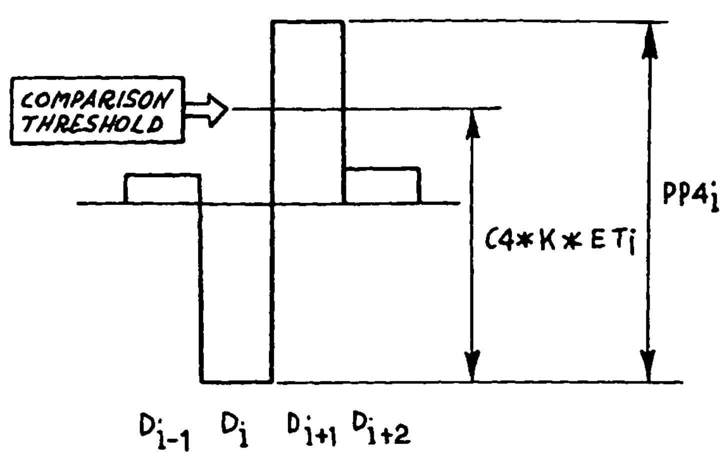

COMPARISON THRESHOLD
$PP4_i$
$C4*K*ET_i$
D_{i-1} D_i D_{i+1} D_{i+2}

FIG. 10

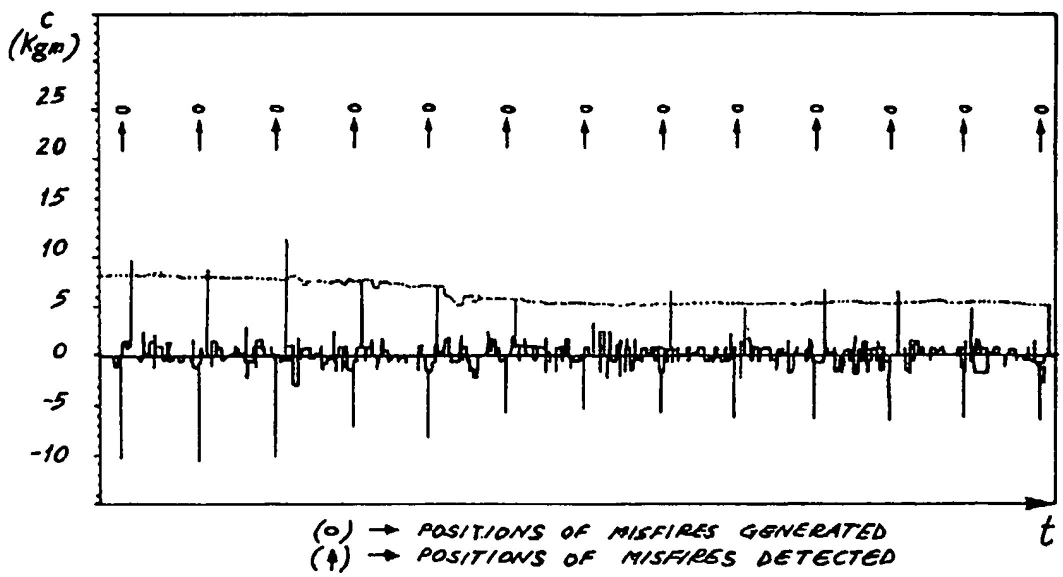

C
(Kgm)
25
20
15
10
5
0
-5
-10
t
(o) → POSITIONS OF MISFIRES GENERATED
(↑) → POSITIONS OF MISFIRES DETECTED

FIG. 11

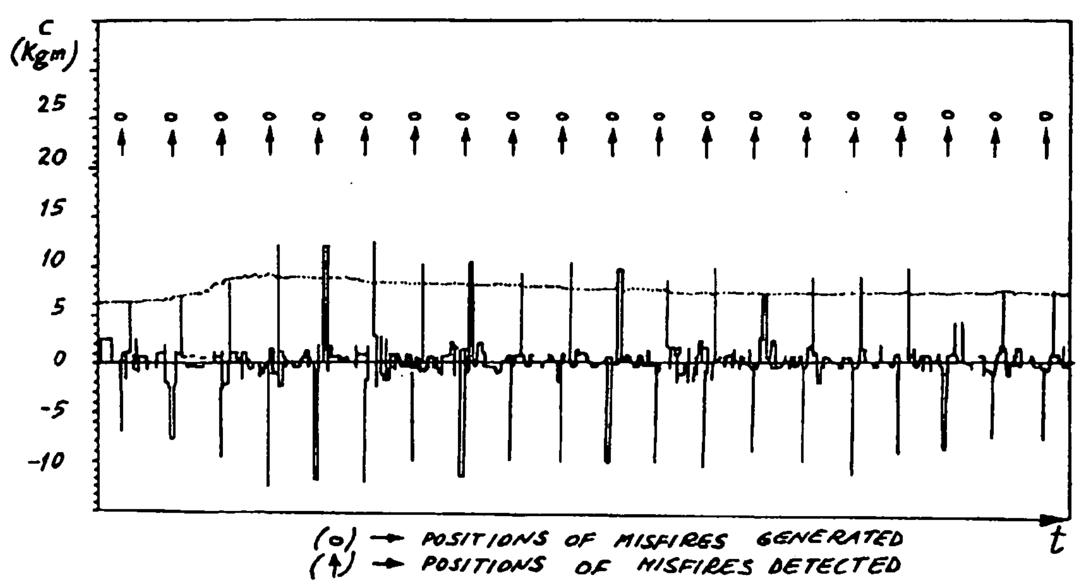

C
(Kgm)
25
20
15
10
5
0
-5
-10
t
(o) → POSITIONS OF MISFIRES GENERATED
(↑) → POSITIONS OF MISFIRES DETECTED

FIG. 12

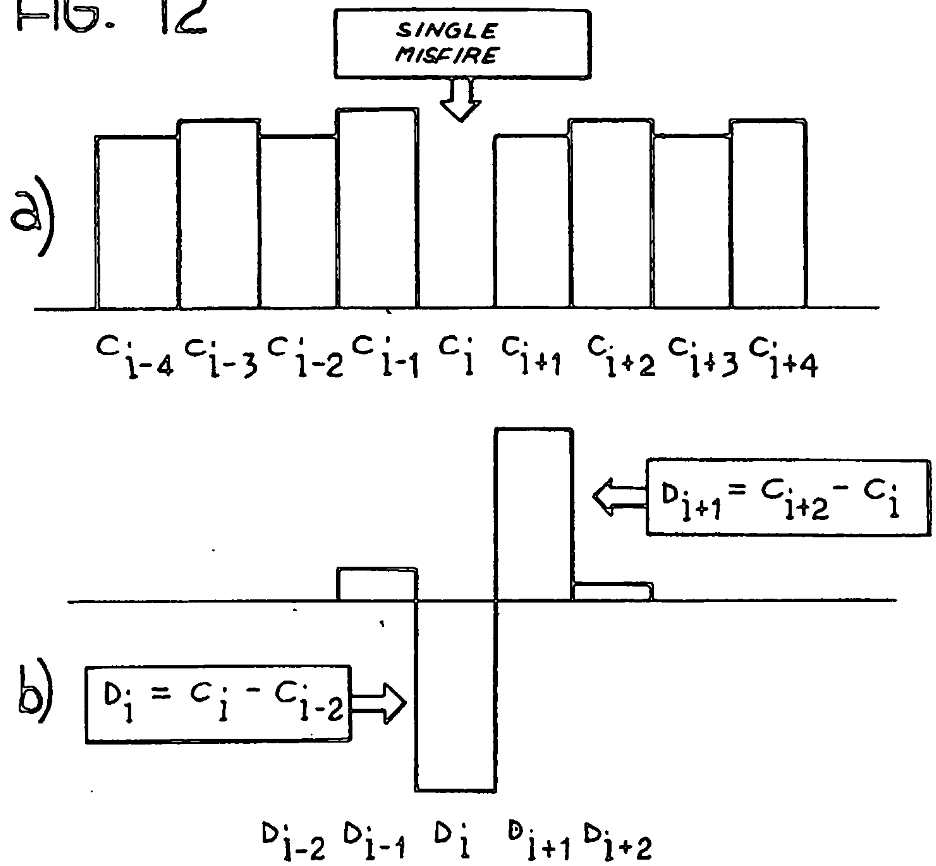

SINGLE MISFIRE
a)
C_{i-4} C_{i-3} C_{i-2} C_{i-1} C_i C_{i+1} C_{i+2} C_{i+3} C_{i+4}
$D_{i+1} = C_{i+2} - C_i$
b)
$D_i = C_i - C_{i-2}$
D_{i-2} D_{i-1} D_i D_{i+1} D_{i+2}

FIG. 13

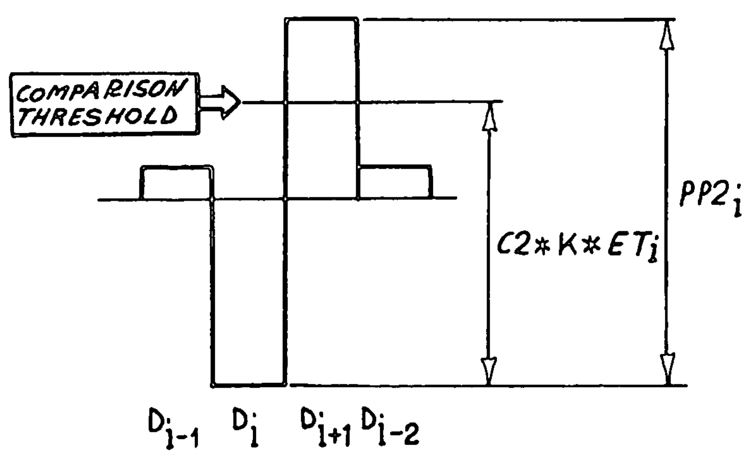

COMPARISON THRESHOLD
$PP2_i$
$C2*K*ET_i$
D_{i-1} D_i D_{i+1} D_{i-2}

FIG. 14

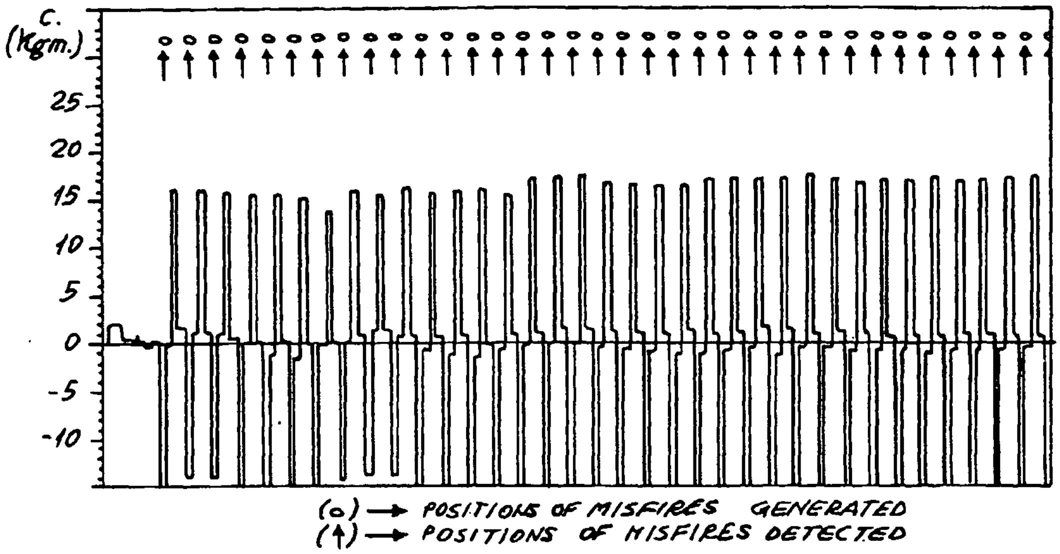
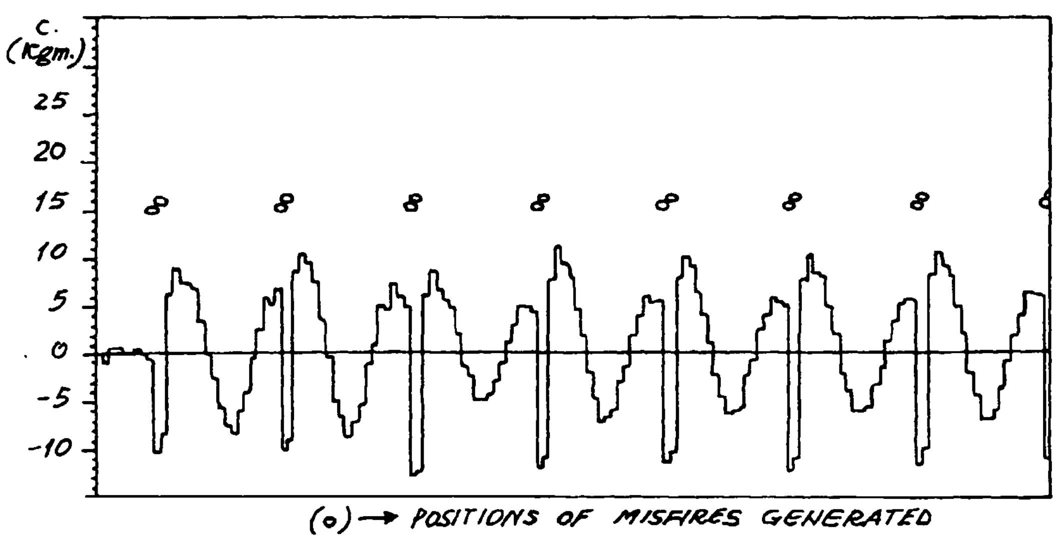

C.
(Kgm.)
25
20
15
10
5
0
-5
-10
(o) → POSITIONS OF MISFIRES GENERATED
(↑) → POSITIONS OF MISFIRES DETECTED

FIG. 15


C.
(Kgm.)
25
20
15
10
5
0
-5
-10
(o) → POSITIONS OF MISFIRES GENERATED